The indium market and compound semiconductors

The recent drop in demand for InP-based devices means that less indium is being consumed by the semiconductor industry, yet indium prices have risen sharply. **Thomas Jansseune** explains why.

In its purest form, indium is the raw material used in the semiconductor industry for InP, InAs or InSb bulk crystal growth and the epitaxial growth of related materials such as GaInAsP. It is introduced as a metal ingot in Czochralski furnaces or vertical gradient freeze furnaces for bulk crystal growth, or as smaller pieces in MBE equipment.

The purity of the indium used for crystal growth is typically 6N or six-nines (99.9999%), which means that the total amount of impurities is less than 1000 ppb. The higher-purity 6N5 or 99.99995% indium, and even higher purities, 6N8 and 7N, are used in smaller quantities, most often in epitaxial growth or for R&D. At these low levels of impurities, maximum concentration limits are often imposed on critical elements. For epitaxial growth by MOCVD, the indium is not present as a metal ingot, but rather as a metalorganic compound, for example trimethylindium.

The high purity of the material requires accurate measurement techniques for the impurities. Typically, glow discharge mass spectrometry (GDMS) would be used to measure a full spectrum of elements, although other techniques are also used. In general, GDMS provides the ability to detect impurities below the detection limit of most other techniques. Recognized laboratories performing GDMS measurements include Shiva Technologies in the US and France, and the National Research Council of Canada.

Uses of indium

While semiconductors are undoubtedly the most demanding application in terms of indium purity, they are not the largest-volume consumer (figure 1). According to the US Geological Survey (USGS), the semiconductor industry consumed 15% of the 335,000 kg of indium produced in 2002, and given the present depressed market conditions for InP-based devices, this could be even less for 2003. However, when the potential of InP-based devices is considered, the use of high-purity indium for semiconductors could account for a much larger share of the total consumption in the future. The purity of the indium used in alloys and in thin-film coatings such as indium tin oxide (ITO), which is primarily used in flat-panel display manufacturing, is typically limited to 2N and 4N8, respectively.

Indium production by country in 2002

Country	*Important indium producers*	*Refinery production (thousand kg)*
Belgium	Umicore	40
Canada	Falconbridge, Cominco	45
China	Huludao, Liuzhou China Tin, Zhuzhou Zinc	85
France	Metaleurop	65
Japan	Nippon Mining, Dowa Mining	60
Peru		5
Russia		15
others		20
total		335

USGS

Table 1. The indium production figures for 2003 will look very different as stricter mining regulations in China and a drop in French output begin to make an impact.

Indium production

To date, no "indium mines" have been opened as the relatively low concentrations of indium in the Earth's crust would not guarantee the economic sustainability of such operations. As a result, indium is recovered as a by-product of zinc and lead production in several different countries (table 1).

The landscape of indium production has been shaken up considerably in the last year. The severe 2001 Nandan mining accident in China and the subsequent stricter mining regulations in the indium-rich Chinese provinces of Guangxi and Hunan has caused the supply of indium concentrates to fall. As a result, Chinese production of indium in 2003 will be considerably less than before as, for example, Liuzhou Zinc stops its 20,000 kg per year indium production in the Guangxi province.

In addition to the problems in China, Metaleurop in France decided to stop producing indium in its Noyelles-Godault plant, taking 65,000 kg of indium production capacity out of the market. Although the USGS figures probably underestimate the Chinese production (more likely figures of 140,000 kg in 2002 and 180,000 kg in 2001 were published in *Platts Commodity News* in June, 2003), the further drop in indium availability in 2003 will be significant.

Because of the still relatively small quantities of indium used in semiconductors at present, producers of virgin indium do not necessarily refine it to semiconductor grade themselves, although some producers such as Umicore and Dowa Mining do so. In order to minimize contamination, Umicore produces

2002 indium market

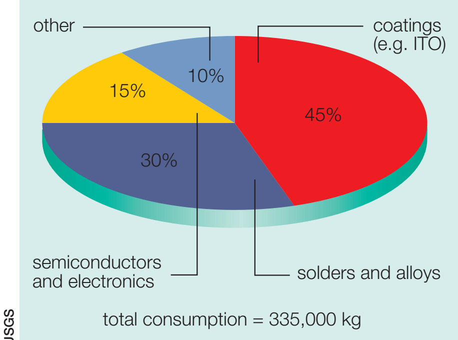

Fig. 1. In 2002, the semiconductor industry accounted for 15% of indium consumption, equivalent to around 50,000 kg.

high-purity indium in a dedicated plant, Umicore Indium Products in Providence, RI, where only products such as high-purity indium and ITO are manufactured. The virgin indium is produced at a separate facility in Hoboken, Belgium. Other producers of high-purity indium include Indium Corporation of America in the US, MCP Group in the UK, and Rasa and Japan Energy in Japan, with Chinese suppliers possibly entering the market in the near future. If the demand for high-purity indium increases and the shortage of indium raw material persists, fully integrated suppliers will probably have an advantage in the marketplace over those who only buy and purify indium. This situation is already being seen in the market for ITO.

Indium price evolution

From the above it is clear that at present the price of indium in general is a function of two variables: the ITO consumption for displays and the indium production. Due to the recent cuts in indium production and the growth of the displays market, the indium price has risen dramatically over the last 9 months (figure 2).

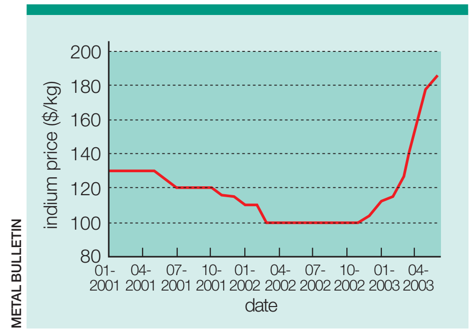

Fig. 2. The price evolution of technical quality (3N7) indium. The price of 6N indium tends to follow the same trend.

The price for 6N indium in large quantities typically follows the same trends as that of technical quality indium as shown in figure 2. For higher purities, the relationship to technical quality material tends to fade because of the high costs involved in employing cutting-edge refining technology and because these materials are often produced according to critical customer specifications.

Due to historically low indium prices, recycling of indium was a non-issue in 2002. Now that the indium prices have climbed up to the $200/kg level, recycling starts to become viable again. In some cases, up to 70% of ITO can be recycled, generating a considerable source for secondary indium, attenuating the effect of reduced virgin indium production.

Outlook

Although at present the needs of indium for InP production and epitaxial growth are modest, they could grow to a considerable share of the indium production in the future. In the short and mid-term, however, no shortages of high-purity indium are foreseen, but the prices will probably continue to increase, following the price of technical quality material. In the long term, and if the consumption of InP-based devices picks up, good control over the entire supply chain will become more critical and may favor the integrated suppliers of indium products as is currently being demonstrated in the ITO market.

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